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Screw Turbine in In-pipe Hydroelectric Power Generation

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Abstract. Utilization of renewable energy sources is a necessity to reduce the consumption of fossil energy sources. On the end of 2021, it was reported that world was experiencing an energy crisis, so the use of renewable energy sources is being something urgent. Renewable energy power generation can be done in large scale to small scale even on household level. Electrical energy independence can be achieved, one way by utilizing available energy sources surrounding house. Several energy sources that can be utilized around the house including water, wind, sunlight, etc. Water as one of energy sources can also be obtained from the water flow in household plumbing systems. In this research, analysis of the output characteristics of generator was carried out from mini generator connected to screw turbine with in-pipe water flow as the energy source. Design and measurement have been done on the prototype to see the output characteristic of generator. Measurement on prototype have shown results to produce 1.56 watt and 9.6 volt at maximum water discharge 0.317 l/s, these results are quite low considering power measured at the turbine reaches about 7.45 watt. With further research, another more efficient and proper configuration can be obtained.

1 Introduction

Renewable energy sources can be easily found even in the household environment. The renewable energy sources can be found in the form of water energy, wind energy, solar energy, etc. However, the use of This renewable energy source is still not optimal. The demand of the use of fossil energy sources is still high. At the end of 2021 it was reported that the world is experiencing an energy crisis caused by scarcity supply of fossil energy sources such as natural gas and coal [1].

The ammount of fossil energy sources are limited in nature, but continuously used to meet the needs of human life. Utilization of renewable energy sources can be done in large scale to small scale even on household level. The use of renewable energy sources around the house also known as harvesting energy surrounding houses. Existing energy sources can be utilized to generate electrical energy by using various types of generators adapted to each of

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these energy sources. Generated electrical energy at each generator then processed using power electronic devices, so that it can be used to charge the battery or directly used to supply electrical household appliances [2].

The source of water energy can come from the water flow in household plumbing systems. Research on electric power generation using in-pipe water flow from household plumbing systems as the source has been done previously [3]. In previous research it was found that, the electric power generated by generator using that kind of water energy source can reach a power of about 3.25 watt. The generator used in that research is a mini compact turbine generator 12V 10W that can be found in the market, which suits to use in $^1/_2$ inch pipe.

2 Fundamental Theory

2.1 Harvesting Energy Surrounding House

Harvesting energy surrounding house refers to the use of various energy sources around the house to meet energy needs, in this case is the need for electrical energy. Energy sources can be in the form of water, wind, solar, and so on. The electrical energy generated from each generator with various energy sources is then processed using power electronic devices, then the generated electrical energy can be directly used to power various household appliances, or stored in batteries [2].

2.2 In-pipe Hydroelectric Power Generation

Energy sources from the water flow are quite widely used, ranging from large scale such as power plants in large dams, to small-scale power plants which are generally built in watersheds or irrigation areas. Several researchers have also conducted research on electric power generation using in-pipe water flow as the source. Pipelines suitable for placing this system are pipes in which water flow tends to be continuous and constant, such as pond or pool pipes, and pipelines in mountain villages where the water is generally allowed to just flow.

Some researchers used water flow in water transmission pipelines [4], some researchers also used waste water flow in liquid waste disposal channels [5], other researchers utilizing a water source in a 100 mm pipe [6, 7]. Utilization of energy sources from water flow in smaller pipes, namely $^1/_2$ inch pipes in household plumbing systems, has been carried out by researcher (me) at thesis research, and obtained the results that the power generated from the system can reach 3.25 watts [3].

2.3 Screw Turbine

Archimedes screw turbine/screw turbine/screw turbines have a spiral/threaded appearance around a cylindrical axis as shown in Fig.1 and are commonly used in sloping water flows with a head even less than 1 m. This type of turbine has several advantages, including it is being suitable for use in areas with adequate water flow but with low head, it has high efficiency with wide range variations in water discharge, and good for low water discharge. [8, 9].

Mechanical power catched by turbine from water flow can be calculated as, [10]

$$P = \tau . \omega \qquad (1)$$

where τ is turbine torque in Nm, and ω is turbine rotation speed in rad/s.

Screw turbine also have several drawbacks, namely the need for a precise design to reduce losses due to the gap between the turbine and the turbine casing [11], In addition, in the vertical installation of a screw turbine (with a certain angle of inclination) is necessary to pay attention to the lower end of the turbine, because if the lower end of the turbine is submerged, it will reduce turbine performance due to reduced effective head of the system [8].

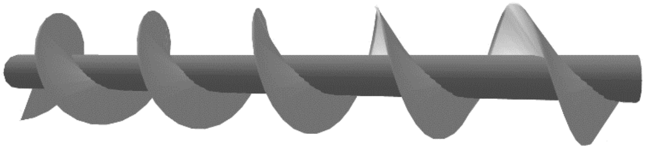

Fig. 1. Single-blade Screw Turbine

2.4 3D Printer

A 3D printer is a printer that can print a 3D design into a 3D model. 3D printers are widely used in making models or certain parts of a prototype. The 3D printer prints a model from melted plastic filament that is shaped according to the design that has been made.

3 Design and Prototype

The system consists of a screw turbine, generator, water inlet and outlet, and casing as shown in Fig.2. Screw turbine used in this research is designed and then be printed using 3D printer. The turbine is single-blade screw turbine, 100 mm in length, and a cycle in every 2 mm so it has total 5 cycles of blade screws. The detail of the turbine can be seen in Fig.3. The turbine then is placed inside the casing made from ½ inch pipe. The turbine shaft is connected to the rotor of generator that placed at the end of casing.

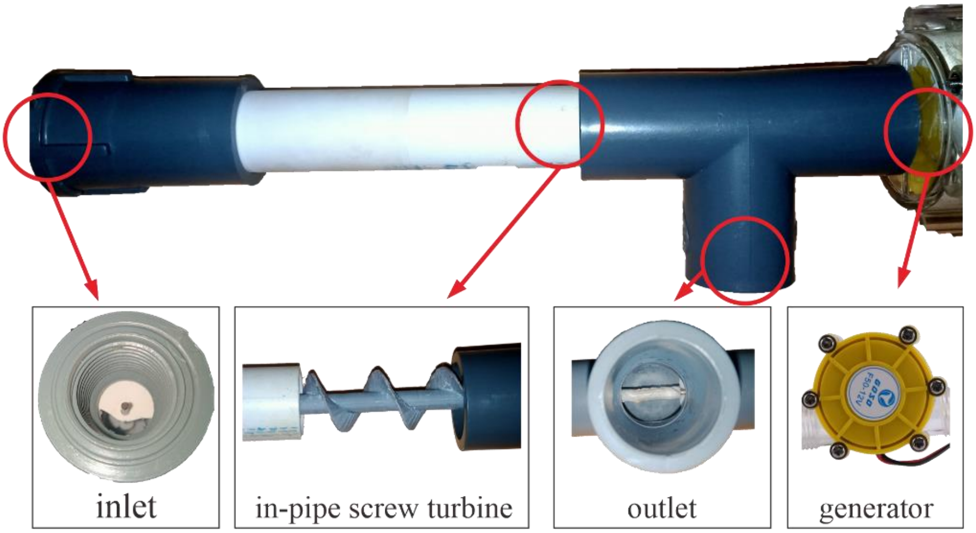

Fig. 2. Prototype

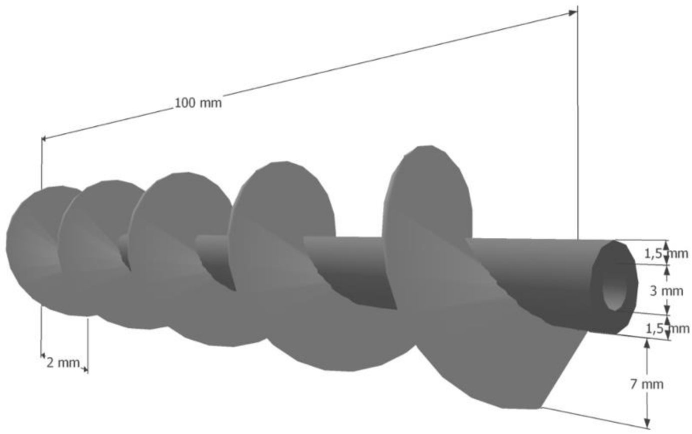

Fig. 3. Turbine details

Generator used in this research is DC mini generator that can be easily found on the e-commerce. Parameters of the generator used in this research can be seen in Table 1.

Table 1. Generator parameters

Parameter	Value
Voltage Rating	12 volt
Power Rating	10 watt
Armature Resistance	10.5 ohm

4 Result and Analysis

Measurement of the prototype was carried out in building H, 3rd floor, Universitas Muhammadiyah Surakarta. Water discharge from the pipeline of this building was measured up to 0.317 l/s, and the turbine starts rotating at water discharge 0.100 l/s. Measurements are done for turbine only and for generator connected to the turbine. From measurements we can get datas of turbine torque and rotational speed with no generator connected to it, and then we also get datas of generator output in no load and loaded condition.

4.1 Turbine

Rotation speed and torque of turbine have been measured. Using these two parameters, power captured by turbine can be calculated using eq.1. The power captured by turbine varies between 0.24 watt at 0.100 l/s to maximum 7.4 watts at 0.317 l/s of water discharge. The datas from turbine measurement can be seen in Table 2.

Table 2. Turbine measurement results

Q (l/s)	τ (Nm)	ω (rad/s)	P (watt)
0.100	0.003	80.5	0.24
0.167	0.005	180.2	0.90
0.200	0.009	239.0	2.15
0.233	0.010	299.2	2.99
0.267	0.014	310.2	4.34
0.317	0.021	354.8	7.45

4.2 Generator

The shaft of turbine then connected to the rotor of generator. Generator runs in two condition, first condition is no-load and second condition is loaded by 60 ohm resistor. At no-load condition, the voltage generated by generator reach 11.46 volt. At loaded condition, the voltage at the output terminal of generator reach 9.6 volt. The power generated by generator reach 1.56 watt. The efficiency of generator is quite low, it varies between 0.2 to 0.28. The datas from loaded generator measurement can be seen in Table 3, and the voltage generated by no-load generator can be seen in Fig. 4.

Table 3. Loaded generator measurement results

Q (l/s)	τ (Nm)	ω (rad/s)	P (watt)	Efficency
0.100	0.003	80.5	0.24	0.20
0.167	0.005	180.2	0.90	0.25
0.200	0.009	239.0	2.15	0.28
0.233	0.01	299.2	2.99	0.28
0.267	0.014	310.2	4.34	0.24
0.317	0.021	354.8	7.45	0.21

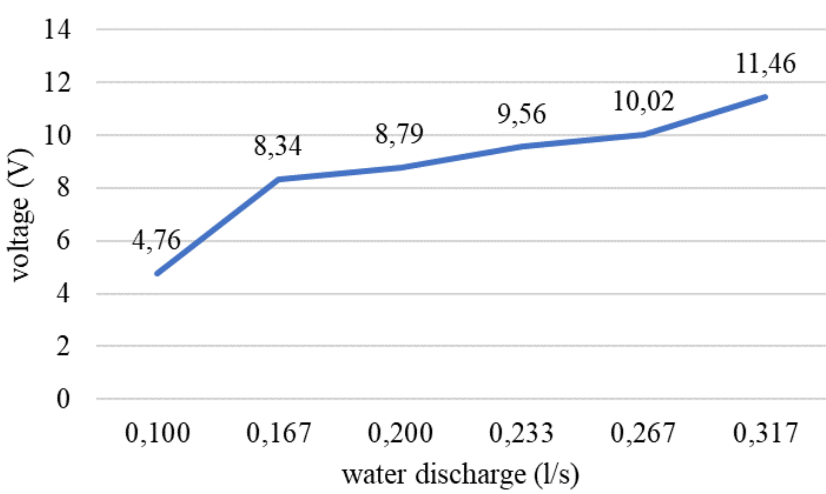

Fig. 4. No-load generator voltage

5 Conclusion

Based on the result of the research, it is possible to use screw turbine in in-pipe hydroelectric power generation, it can convert about 7.4 watts of power from in-pipe water flow. Another advantage of the turbine is that it can be installed neatly inside the pipe. This system may suitable to be installed in pool pipeline, houses in mountain areas, and so on, where the water flow tends to be continuous and constant. However, the generator used in this experiment may not be suitable for the turbine, because it can only convert about 1.5 watts of power, or only about 0.2 in efficiency. For further development, the system requires more suitable generator for its turbine, and the generator must be desaigned so it can be placed inline with the pipe and also must compact, so the system can not only achieve higher efficiency but also can be placed in the middle of household plumbing system without disturbing the plumbing original design.

References

1. T.F. Arbar. *Krisis Energi Hantam Dunia, Ramai-ramai 'Berebut' Batu Bara?* 2021 October 4th [cited 2021 November 15th]; Available from: https://www.cnbcindonesia.com/news/20211004080800-4-281092/krisis-energi-hantam-dunia-ramai-ramai-berebut-batu-bara.
2. T. Taufik. *The DC House project: An alternate solution for rural electrification*. in *IEEE Global Humanitarian Technology Conference (GHTC 2014)* (2014)
3. R.N. Ahmad. *Topologi dan Kajian Kinerja Multi Konverter Arus Searah untuk Multi Mini Generator-Hidro*, in *Teknik Elektro*. Universitas Diponegoro: Semaran (2021)
4. Y. Itani, M.R. Soliman, and M. Kahil, *Recovering energy by hydro-turbines application in water transmission pipelines: A case study west of Saudi Arabia.* Energy, 211: p. 118613 (2020)
5. J. Titus, and B. Ayalur, *Design and Fabrication of In-line Turbine for Pico Hydro Energy Recovery in Treated Sewage Water Distribution Line.* Energy Procedia, 156: p. 133-138 (2019)
6. J. Chen. *A novel vertical axis water turbine for power generation from water pipelines.* Energy, 54: p. 184-193 (2013)
7. N. Hasanzadeh. *Investigation of in-pipe drag-based turbine for distributed hydropower harvesting: Modeling and optimization.* Journal of Cleaner Production, 298: p. 126710 (2021)
8. E. Erinofiardi, M. Syaiful, and A. Prayitno, *Electric Power Generation from Low Head Simple Turbine for Remote Area Power Supply.* Jurnal Teknologi, 74 (2015)
9. A.I. Weking and Y.P. Sudarmojo, *Prototype Design of Microhydro using Turbine Archimedes Screw for Simulation of Hydropower Practical of Electro Engineering Students.* Journal of Electrical, Electronics and Informatics; Vol 3 No 1: JEEI (February 2019) (2019)
10. S.J. Chapman. *Electric Machinery Fundamentals*. 4th ed., McGraw-Hill comp., New York: Elizabeth A. Jones (2005)
11. W.D. Lubitz. *Gap Flow in Archimedes Screws* (2014)